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Rehabilitation following rotator cuff repair: a narrative review

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ABSTRACT
Optimum rehabilitation following Rotator Cuff Repair (RCR) remains a contentious topic. A wide range of often conflicting evidence and opinion exists regarding several aspects of the rehabilitation process. This has resulted in a wide variety of different post-operative protocols and uncertainty regarding the need for immobilisation, initiation of exercises and rehabilitation progression. In this climate of uncertainty, it appears that rehabilitation protocols have remained largely unchanged for over two decades despite the large volume of new evidence. This narrative review examines common assumptions that surround rehabilitation following RCR in the light of contemporary evidence. It is hoped this will aid clinicians when making decisions for this patient group.

KEYWORDS
Rotator cuff; repair; rehabilitation; review; physiotherapy; shoulder

Introduction

Disorders of the rotator cuff (RC) are considered the most common cause of shoulder pain [1], with an increasing prevalence of RC tears with increasing age [2]. While many patients with RC tears are asymptomatic, others experience ongoing disability and pain [3]. While uncertainly still exists regarding the optimum management of patients with a RC tear [4], surgical repair remains a common treatment option [5–7].

Following rotator cuff repair (RCR), a programme of rehabilitation is undertaken. There are many uncertainties surrounding post-operative rehabilitation including balancing the protection of the repaired and healing tissue with the desire to optimise return to work and other functional and recreational activities [8]. Uncertainty regarding the optimal loading during different stages of rehabilitation, and the individual nature of patient and tear characteristics, contributes to variability in post-operative protocols [9]. Perhaps because of this uncertainty, more conservative approaches are pervasive, with 4–6 weeks of post-operative sling immobilisation and restricted resumption of active movement remaining the most common approach [9–11]. Furthermore, perceptions of optimal treatment often vary between health professionals. For example, Kane et al. [12], found that physiotherapists tend to favour shorter periods of immobilisation and more progressive rehabilitation, whereas surgeons tended to favour more conservative protocols with longer periods of immobilisation.

The purpose of this review is to examine the wide range of evidence regarding tendon healing, sling immobilisation, initiation of movement and rehabilitation progression following RCR with the aim of providing clinicians with information that will facilitate decision making in the context of current uncertainty.

Tendon healing following RCR

Healing following RCR has been described as progressing through inflammatory, proliferation and remodelling phases [13]. During the inflammatory phase, the healing tendon is supported by a weak scar which is formed during the first 14 days [14]. During this initial phase the configuration of anchors and sutures used during the repair provide the majority of its mechanical strength [15]. After this initial period, the proliferation phase commences, where fibroblast proliferation and collagen deposition are increased [16]. The remodelling phase overlaps the proliferative phase and is characterised by organisation of collagen and tenocytes in alignment with the direction of stress and the gradual increase in tensile strength due to replacement of type III with type I collagen. This process can continue for months or even years [17].

Animal models illustrate uncertainty regarding the optimum loading environment following RCR.

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Complete removal of load does not appear to benefit tendon to bone healing, as inferior mechanical properties of repaired rat RC tendons have been observed when the supraspinatus was paralysed using botulinum toxin [18,19]. Other studies investigating the effect of loading on healing following tendon to bone repair have produced conflicting results. Li et al. [20] found that continuous passive motion (CPM) enhanced fibroblastic activity in a rabbit model, whereas Peltz et al. [21] observed no difference in collagen organisation or biomechanical strength when passive motion was compared to immobilisation in a rat model. Zhang et al. [22] observed reduced biomechanical strength of repaired rat RC tendons when free activity was allowed compared to immobilisation, (both with and without passive motion) and Wada et al. [23] found improved tendon maturation in a murine model when specimens were immobilised compared to those that completed a regime of treadmill running. Conversely, Zhang and Chen [24] found that a regime of treadmill activity in a murine model enhanced biomechanical properties and tendon to bone maturity. The one consistent finding throughout these studies appears to be the gradual increasing maturity and mechanical strength of the repairs over time.

These studies highlight the complex nature of the healing process following RCR, and many questions remain for clinicians involved in post-operative rehabilitation of this patient group. While it appears loading can be both a positive and negative stimulus for healing, what represents optimum loading during different stages of the healing process remains unknown. The inference that can be taken from animal studies is also limited due to the substantial differences in the post-operative rehabilitation programmes evaluated, for example treadmill running, free activity, and passive motion, and likely differences in healing rates between animals and humans [25].

Factors effecting rotator cuff healing

A plethora of patient and tear related factors have been reported to influence healing following RCR [26]. In their meta-analysis, Raman et al. [27] found fatty infiltration ($n = 505$, OR 9.34, 95%CI 4.22–20.70) had the strongest negative effect on repair integrity, followed by multiple tendon involvement ($n = 176$, OR 6.02, 95%CI 2.47–14.69), larger tear size ($n = 1352$, OR 4.27, 95%CI 2.93–6.23), increasing age ($n = 1312$, OR 2.83, 95%CI 2.29–3.50), and presence of Diabetes Mellitus (Dm) ($n = 390$, OR 2.13 95%CI 1.16–3.90). Other patient related factors such as smoking status, obesity and osteoporosis may also affect healing rates, although the influence of these factors remains unclear [28–30].

Healing following RCR is a complex multifactorial process. Many prognostic factors for RC healing are closely related and determining the significance of a single prognostic factor on healing is challenging. For example, while increasing age has been associated with lower healing rates, it is debatable how significant age is taken in and of itself. In a study of 1600 consecutive RCR, Dieblod et al. [31] found that age was independently predictive of poorer healing rates when multivariate analysis was used to control for other confounding variables. However, the OR (1.05 95%CI, 1.03–1.06) suggests age alone is not a strong predictor of repair outcome. Likewise is true of pre-operative tear size. For example, a prospective study of 256 repairs by Rashid et al. [32] found only massive tears (>5cm) were independently predictive of failed healing (OR 0.18, 95%CI 0.05–0.61) when adjusted for age, sex, hand dominance and previous corticosteroid injections.

While improved knowledge of factors that influence healing might be useful in aiding selecting appropriate patients for RCR [28], it is less clear how these factors should influence post-operative management and rehabilitation. Kokmayer et al. [33] propose a prognosis-based model where a more conservative approach is adopted in the presence of poor prognostic factors for healing. In their systematic review, Thompson et al. [34] concluded that clinicians should adopt a more conservative rehabilitation approach in patients with larger tears (>3 cm). To our knowledge, there are no clinical trials that have investigated this type of prognosis driven rehabilitation. Clinically, adopting this type of approach is difficult due to the uncertain and conflicting evidence in this area. Due to the interconnected relationship between many of these potential prognostic factors, quantifying the effect that these individual factors have on healing is extremely difficult [35]. Furthermore, these recommendations are based on the assumption that more progressive rehabilitation may negatively influence healing. This assumption requires close examination due to the beneficial effects of load on healing [36] and potential negative effects of immobilisation on muscle and tendon health [37].

Post-operative stiffness

Shoulder stiffness is one of the most frequent complications following RCR [38]. It has been suggested that a certain degree of post-operative stiffness may reflect a positive healing response [39]. However, while for some, post-operative stiffness is mild and transient [40] for others it can be debilitating and long lasting. It has been estimated that between 3.3% and 4.9% of patients develop significant and persistent post-operative stiffness that requires further surgical intervention [41,42].

A systematic review by Denard et al. [41] identified a range of potential factors associated with post-operative stiffness, such as patients aged <50, smaller tears, repairs of Partial Articular Surface Tendon Avulsion (PASTA) lesions and pre-operative diagnosis of calcific tendonitis or adhesive capsulitis. It is thought that early mobilisation following RCR may help prevent post-operative stiffness. One small non-experimental study [43] found no cases of stiffness (as defined as patient dissatisfaction with their range of motion) in a group of 79 patients with at least one risk factor (for developing stiffness) who were targeted with immediate closed chain mobilisation following RCR. However, overall evidence is limited, and it is unclear if different rehabilitation strategies have a role in preventing cases of long-term stiffness following RCR.

Early mobilisation vs immobilisation

When to initiate movement following RCR continues to be a topic for debate and is reflected in the large number of studies that have been published on the topic over the last 10 years. Combining sling immobilisation with exercises to mobilise the shoulder (usually passive) is a popular approach that is thought to help minimise pain and stiffness [8]. However, there continues to be some concern that initiating passive motion in the initial period following RCR may lead to reduced rates of healing. This has led some to suggesting that stricter immobilisation is required to protect the repair site during this early phase of healing [44].

Mazuquin et al. [45] undertook the most recent systematic review and meta-analysis on early mobilisation following RCR (5 randomised controlled trials, 410 participants) and did not observe a statistically significant difference in healing between early and delayed rehabilitation ($p = 0.31$). The number needed to harm (NNH) was calculated with regard to re-tear rates and indicated that 32 patients treated with early mobilisation were needed for one to have a re-tear which could potentially be attributed to early mobilisation. This may suggest that early mobilisation does not play a significant role in failed healing or re-tear following RCR. Equally, questions remain regarding the potential benefit of early mobilisation, as no statistically significant difference was found for range of motion, pain or functional scores between early and delayed mobilisation. Although it remains uncertain whether early mobilisation may adversely affect healing in larger RCR (>3 cm) [35,46], it is not yet possible to draw definitive conclusions due to insufficient data comparing early and delayed rehabilitation for larger repairs (>3 cm).

Variability of the included studies regarding surgical technique, method of immobilisation, and timing of mobilisation as well as the variable quality of the original studies makes interpretation of these results challenging. In the presence of this uncertainty there remains great variability in how this evidence is implemented in clinical practice. In a recent survey, 129 clinicians were asked to describe their typical practice in patients of different tear sizes following RCR [11]. Regarding early mobilisation, 62% reported they would recommend passive range of motion in the first week following RCR in a patient with a small (2 cm) tear with 50% recommending the same in a patient with a large (4 cm) tear. This illustrates, that despite consistent evidence that early mobilisation does not adversely affect healing, particularly in small to medium size repairs [45], many clinicians remain reluctant to advise early mobilisation following RCR.

Sling immobilisation

Most protocols advocate post-operative sling use for a period of 4–6 weeks following RCR [9,11]. The driver for this approach appears to be the concern that early discontinuation of the sling will result in increased motion and strain which may be detrimental to the healing process [46]. Discontinuation of the sling typically involves active use of the arm for activities of daily living as dictated by patient comfort, and therefore theoretically represents an increase in load compared to immobilisation with or without early mobilisation. It is poorly understood what influence this increase in load may have on recovery and healing rates and uncertainty remains regarding the optimum method and duration of sling immobilisation.

It has been argued that immobilisation using an abduction sling may have to potential to improve outcomes such as pain and healing following RCR due to reduced strain on the healing tissues and improved blood flow [47]. At present there is a lack of clinical evidence to support this. Hollman et al. [48] randomised 36 patients to either an abduction sling or standard anti-rotation sling and did not observe any significant difference in pain, function (Western Ontario Rotator Cuff (WORC) index) or range of movement (ROM). More recently Ghandor et al. [49] also observed no significant difference in pain, function (Constant-Murley Score) or muscle strength in 106 patients who were randomised to either an abduction brace or a standard sling. Neither of these studies investigated RC integrity, so it is not possible to draw any conclusions regarding the influence of different slings on tendon healing.

Several randomised controlled trials have examined the effect of different periods of sling use. Koh et al. [50] observed a greater rate of stiffness (as defined by failing to achieve either 120 degrees flexion, internal rotation to L3 level or 20 degrees of external rotation) at 24-month follow-up when 88 patients were randomised to 8 weeks sling immobilisation (using an abduction sling) compared with 4 weeks ($p = 0.04$). Pain ($p = 0.2$) and Constant score ($p = 0.56$) did not differ significantly between groups. Jenssen et al. [51] compared 118 patients immobilised for 3 weeks in a standard sling compared to 6 weeks in an abduction sling. They did not observe any significant difference in Constant score ($p = 0.36$) at 12-month follow-up, although they did find that internal and external rotation range was statistically superior (mean difference 7° and 8° respectively, $p < 0.05$) in the group that had been immobilised for three weeks at six week follow-up.

Other randomised controlled trials have sought to compare a period of sling immobilisation with no immobilisation following RCR. Sheps et al. [52] compared 189 patients with all tear sizes following mini-open RCR and found that patients who were instructed to discontinue the sling as tolerated had significantly better range of abduction (mean difference 12.9° $p = 0.002$) and scapula plane elevation (mean difference 14°, $p = 0.006$) at 6-week follow up compared with 6 weeks sling immobilisation. Tirefort et al. [53] randomised 80 patients with small to medium size RCR to either no immobilisation or 4 weeks sling immobilisation and observed a small but statistically significant difference in pain scores at 6 months (0.7 points on the VAS scale, $p = 0.031$ and 6.4 points on the single assessment numeric evaluation, $p = 0.011$), as well as superior elevation at 3 months (mean difference 13.2°, $p = 0.015$) favouring the group who were not immobilised. Sheps et al. [54] randomised 206 patients of all tear sizes to either no immobilisation or 6 weeks sling immobilisation and observed superior flexion (mean difference 11.1°, $p < 0.03$) and abduction (mean difference 8.3°, $p < 0.03$) in the no immobilisation group. None of these studies observed any statistically and clinically significant difference in patient reported outcomes between the groups.

Four of these studies [50,51,53,54] investigated healing as a secondary outcome, and none demonstrated a significant difference in healing rates between the different approaches. Although this finding should be interpreted with caution, as the studies were not adequately powered to examine this outcome, this suggests that any increase in load resulting from earlier sling discontinuation may not be a significant factor effecting healing rates.

While there is a growing body of evidence regarding the objective effects of different approaches to sling use, there is limited information regarding patients' perspectives and experiences. Nassiri et al. [55] investigated sling compliance in a prospective study of 128 patients following RCR and anterior shoulder stabilisation. They found that while patients initially found the sling a source of comfort, compliance tended to reduce as time progressed, particularly in procedures performed on the dominant arm. This may reflect that longer periods of immobilisation are difficult for many patients to manage. More information regarding patients' perceptions of sling use would be valuable in the context of uncertainty regarding best practice.

There are several potential detrimental effects that occur as a result of prolonged immobilisation, such as muscle/tendon atrophy, patient distress/frustration and delayed return to functional and occupational activities [56]. These studies suggest there may be advantages to shorter periods of sling immobilisation, such as faster recovery of range of motion and reduced short term pain. It is possible, therefore, that immobilisation following RCR may not be helpful or the most appropriate strategy and that patients can be mobilised judiciously post-operatively without adversely effecting healing rates; or perhaps such approaches might even facilitate healing. Large randomised controlled trials that are adequately powered to detect differences in healing rates, of all tear sizes, would provide more clarity to this argument.

Initiating active exercise

While there is a large and ever-growing body of evidence regarding early passive motion following RCR the evidence to support the initiation of active exercise is lacking [57]. Kluczynski et al. [58] performed a meta-analysis comparing early versus delayed active exercise following RCR. They found that early active exercise was only associated with inferior healing in larger tears (>3cm). This review included non-randomised and non-comparative studies, so has a high risk of bias and caution is required when interpreting the result. A small randomised controlled trial by Duzgun et al. [59] randomised 29 patients to either an accelerated protocol or standard care following RCR. They found that an accelerated protocol including immediate active exercise resulted in superior functional scores (15.47 points on the Disabilities of the Arm Shoulder and Hand questionnaire, $p < 0.05$) to the traditional protocol at 16-week follow-up. However, this study did not investigate repair integrity and the follow-up period was only 24 weeks. Further research is needed to draw definitive conclusions regarding active rehabilitation following RCR.

Load progression

There is a lack of evidence regarding the implementation of different strategies in the latter stages of rehabilitation following RCR. Subsequently, most guidelines base their recommendations on either previous protocols, expert opinion, or applied knowledge electromyography (EMG) data to guide the gradual application of load [8,13,60].

The gradual application of load to the healing tendon is a sound principal and is known to stimulate collagen synthesis and improved tendon mechanical properties [16,36]. A core concept for rehabilitation following RC tendon repair is the application of appropriate mechanical stresses based both on the healing processes discussed above [8,13]. The difficulty, however, is knowing if the applied load is beneficial or deleterious for the individual patient given the lack of definitive knowledge regarding healing times and repair strength at different stages of the rehabilitation process.

A popular approach to load progression following RCR involves starting with passive range of motion, which progress to active assisted, active, and finally resisted exercises [10]. This is certainly one way of progressing load, but EMG studies demonstrate the problem with relying solely on this approach to guide rehabilitation activity. Many active exercises have been shown to produce less RC activity compared to commonly used passive exercises and activities of daily living [61–63]. For example, an active incline shoulder press may produce lower supraspinatous EMG activity that the commonly used pendulum exercise [62], or for that matter donning and doffing a sling [63]. Similarly, over reliance on EMG data is also problematic. While EMG data can be useful at determining muscle activity during different movements, it does not tell us how much strain is being placed on the healing RC [62]. Therefore, EMG data alone does not offer a practical approach that clinicians can use to inform rehabilitation progression [62].

In clinical practice the progression of load is a complex process which involves the interplay between multiple different factors. Rehabilitation programmes can be manipulated in a variety of ways to increase or decrease the overall load. It has been demonstrated that increasing angle of elevation, the length of the lever arm and moving from closed to open kinetic chain movements can all increase RC activity [63,64,65]. Further to this, exercise parameters such as speed, volume, frequency and resistance can be changed to individualise the load to the patient's goals, ability, and stage of recovery. An additional consideration is that the level or recruitment of the RC muscles is affected by the direction of movement. Supraspinatous and Infraspinatous activity has been shown to be higher during 'push' or flexion-based activities, whereas subscapularis is more active during 'pull' and extension-based activities [66,67]. The direction of resistance and tension is therefore worth consideration depending on the type of repair and tendons involved.

In line with the described approach to progression, (moving from passive to active-assisted to active movement and then resisted exercise) timeframes are typically specified to inform the progression. For example, perform passive exercises for 6 weeks, progressing to active assisted and active exercise with 'strengthening' commencing at 12 weeks [8]. However, given the ambiguity regarding healing rates and uncertainty regarding the effect of loading, it is difficult to see how using time-based approaches to guide postoperative rehabilitation is helpful. Likewise, separating the rehabilitation process into arbitrary phases potentially introduces artificial limitations to activity that are not supported by current evidence. Instead, a collaborative and flexible approach where the patient, physiotherapist and surgical team contribute to the discussion regarding the rehabilitation process would be a prudent strategy [68]. In this approach, rehabilitation can be gradually progressed, or regressed if necessary, in a step-by-step process based on the individual patient's ability to perform the exercise or movement with quality, control and with well controlled symptoms. Core to this principal is that patients can be educated to monitor themselves for signs of mechanical overload and actively participate in decisions regarding rehabilitation progression [69].

Conclusion

There are key challenges that patients and clinicians face following RCR. The evidence illustrates the complexity and individual nature of healing and does not, in our view, support definitive timeframes that can be used in the rehabilitation process. While it is generally accepted that load can be a positive stimulus for tissue healing, the ideal 'dosage' of load during different stages of healing following RCR remains unknown. Current popular rehabilitation strategies continue to be based on common assumptions that require closer scientific scrutiny.

While the effect of load on healing rates continues to be a source of debate, current evidence has not demonstrated a definitive difference in healing rates between different rehabilitation strategies. The introduction of guidelines that allow earlier mobilisation and shorter periods of sling immobilisation show some promise with regard to pain and range of motion, but more large randomised controlled trials are required to understand what effect this approach may have on healing following RCR. Furthermore, very little is known regarding patients' experiences and perceptions of post-operative care following RCR. An improved understanding of the patients' voice may also allow clinicians to make more informed decisions regarding their rehabilitation approach.

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The authors declare that there is no conflict of interest.

Contributorship

DH conceived the idea and drafted the manuscript. CL and BM provided feedback as the manuscript was developed. LM assisted in reviewing articles.

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